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Evaluation of a *Myriophyllum spicatum* Decline in Reservoirs of the Tennessee and Cumberland Rivers

by *Craig S. Smith, John W. Barko*

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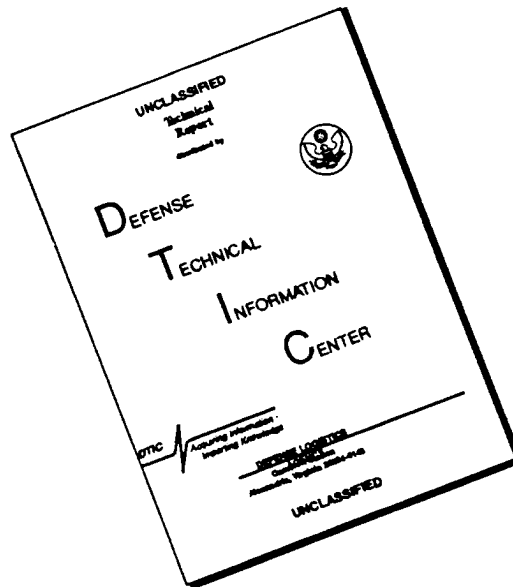
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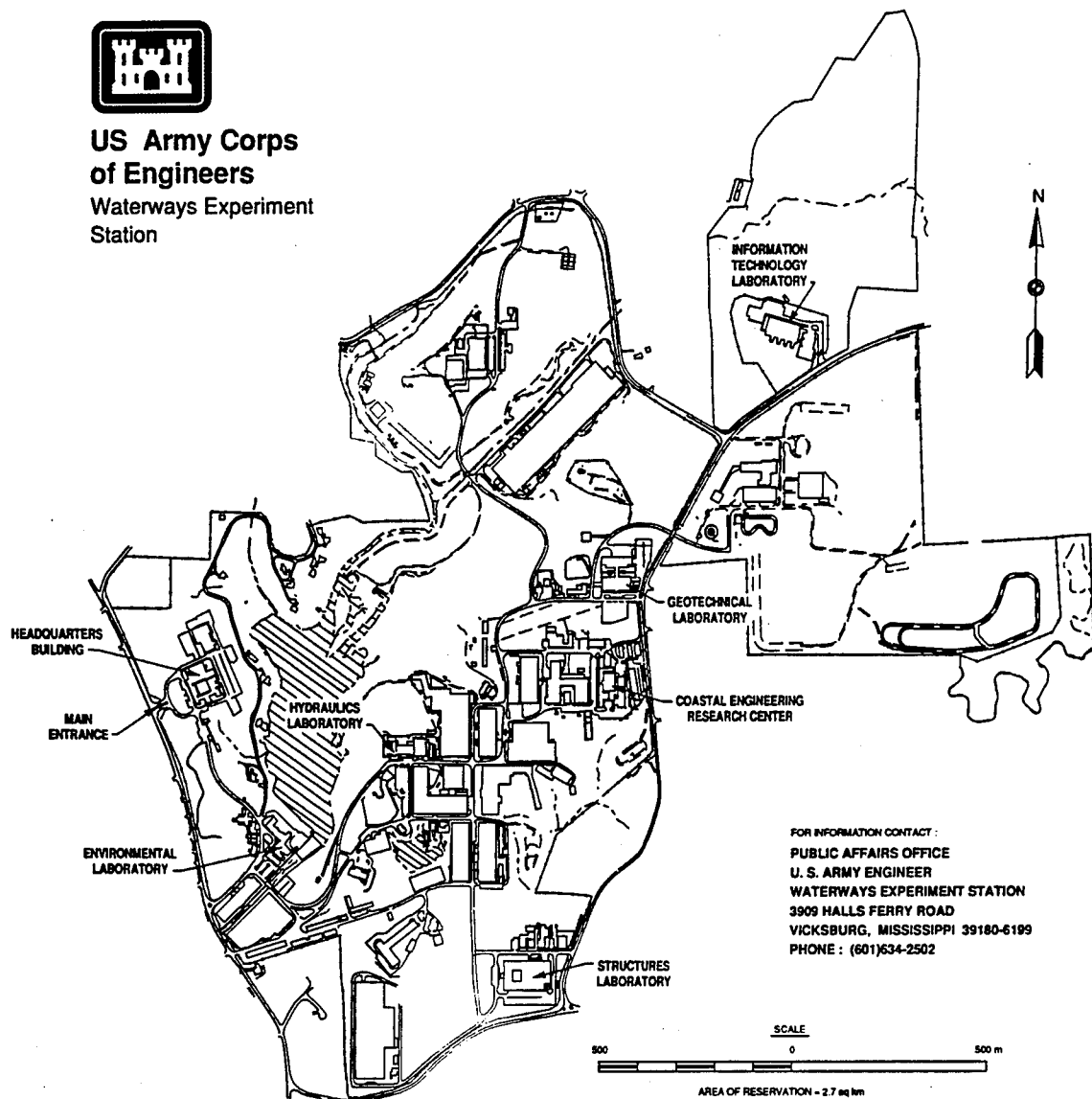
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Preface

The work reported herein was conducted as part of the Aquatic Plant Control Research Program (APCRP), Work Unit 32805. The APCRP is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation No. 96X3122, Construction General. The APCRP is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Mr. Robert C. Gunkel, Jr., was Assistant Manager, ERRAP, for the APCRP. Program Monitor during this study was Ms. Denise White, HQUSACE.

Principal Investigators for the work reported herein and the authors of this report were Dr. Craig S. Smith, WES Eau Galle Aquatic Ecology Laboratory, Spring Valley, WI, and Dr. John W. Barko, Ecosystems Processes and Effects Branch (EPEB), Environmental Processes and Effects Division (EPED), EL, WES, Vicksburg, MS. Messrs. Doug Murphy, Buff Crosby, David Webb, Larry Mangum, Lee Hill, John Upton, and Richard Starkey, Tennessee Valley Authority; Messrs. Carl Crews, Terry Martin, Steven Shaw, Marice Simpson, and Mark Vaughn, U.S. Army Engineer District, Nashville; and Meses. Dwilette McFarland, Wanda Dee, and Susan Fox and Messrs. David Reed, Kevin Pigott, and Ashley Boyd, EPEB, provided valuable assistance in completing the field and laboratory portions of this work.

This investigation was conducted under the general supervision of Dr. John W. Keeley, Director, EL, and Mr. Donald L. Robey, Chief, EPED, and under the direct supervision of Dr. Richard E. Price, Acting Chief, EPEB.

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1 Introduction

After invading a new location, populations of exotic submersed macrophytes often exhibit a pattern of explosive growth, followed after 10 to 15 years by a noticeable decline (Carpenter 1980; Smith and Barko 1990). Many factors have been proposed as possible causes of declines (see Carpenter 1980), but little evidence supports the importance of any of these in causing specific declines (see Smith and Barko 1990).

A substantial decline in submersed vegetation occurred throughout mainstream Tennessee Valley Authority (TVA) reservoirs in 1989 through 1991 (Figure 1), coinciding with declines of submersed species in the upper Mississippi River (Rogers 1994) and the tidal Potomac River (Carter et al. 1993).

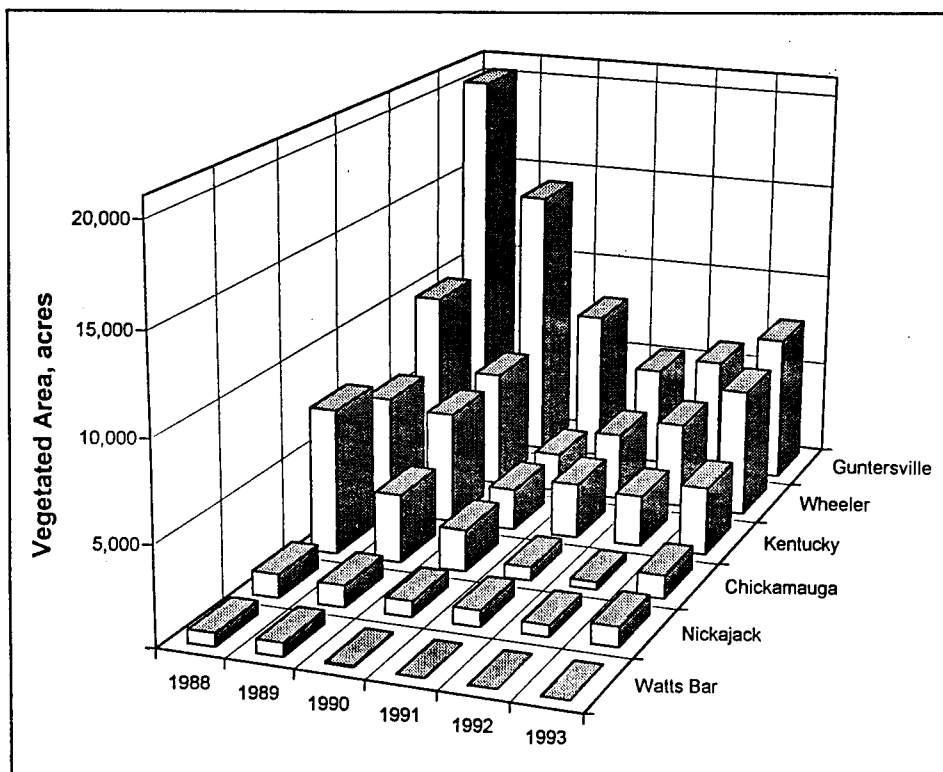


Figure 1. Submersed macrophyte coverage in mainstream TVA reservoirs (Bates and Smith 1994)

During the summer of 1988, the eastern United States experienced a severe drought, and macrophyte coverage in the TVA reservoirs reached record levels. In the years 1989 through 1991, spring rainfall was above normal, resulting in high water flows and increased turbidity. Depending on the TVA reservoir, submersed macrophyte coverage declined over a 2- or 3-year period. Improved growing conditions led to a partial recovery of aquatic vegetation by 1992 or 1993 in most of these reservoirs. One exception is Watts Bar Reservoir, the TVA reservoir into which Eurasian watermilfoil was first introduced, where recovery is not evident.

This report describes results of studies of environmental factors associated with declines. Sites were examined where populations of *Myriophyllum spicatum* (Eurasian watermilfoil) had been stable, declined and then recovered, or never existed. At each site, selected environmental conditions and plant cover were evaluated. Sediments were collected and returned to the laboratory, where they were bioassayed for their ability to support plant growth and their physical properties were analyzed.

2 Methods

Sites where *M. spicatum* populations had (a) remained constant, (b) declined, (c) declined and recovered, or (d) never invaded were examined to determine conditions that may have contributed to differences in the ability to support submersed macrophyte growth. Sites were located primarily in TVA reservoirs, where long-term records of plant cover are available from aerial photography, and in reservoirs on the adjacent Cumberland River (Barkley and Old Hickory), where *M. spicatum* has invaded more recently and where populations are generally expanding (Figure 2).

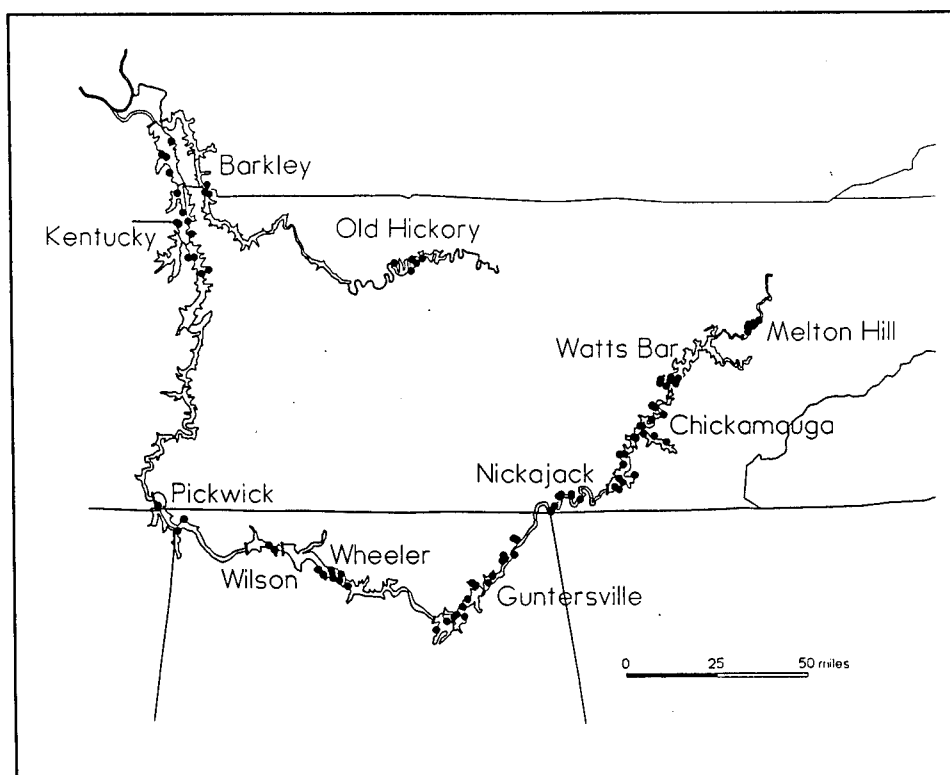


Figure 2. Locations where environmental data and sediment cores for bioassays were collected

The vegetation cover history of sites was determined from aerial photographs taken in 1987 or 1988, 1990, and 1992. Sites were selected to represent a range of environments (e.g., overbank and embayment). Sites were taken from locations where *M. spicatum* beds had been sufficiently large or were close enough to distinct landmarks so that it was possible to be reasonably sure of being within the former bed limits when collecting samples in the field. Compass bearings to two to four recognizable landmarks were recorded at sample locations.

Basic environmental data were recorded for each sample site. These included a Secchi disk measurement, observations of plant cover, and information concerning any recent aquatic plant management. *Myriophyllum spicatum* cover was recorded in semiquantitative categories ranging from absent to very dense. Presence and species composition of any other submersed vegetation was noted.

Sediments from the sample sites were collected and bioassayed for their ability to support *M. spicatum* growth. Sediment cores were collected in 10-cm diam polyvinyl chloride (PVC) tubes 28 cm long. Core tubes were filled with intact cores of sediment by inserting the core tube vertically into the sediments except where dense or rocky sediments made it impossible to insert the corer completely. In these cases, additional surficial sediments were added to the top of the core to fill the tube. Cores were stored underwater in a cold room (approximately 5 °C) until they could be bioassayed. Three experimental runs were required to bioassay all of the core samples.

Coarse sand was added to the top of the cores to minimize sediment resuspension and nutrient loss, and each core was planted with four 15-cm sprigs of *M. spicatum* from greenhouse stock cultures. For each experimental run, four additional core tubes were filled with sediments from Browns Lake, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, and planted to provide a measure of growth on a known reference sediment. After planting, each core was inserted into the base of an individual acrylic column that was then filled with growth medium (Smart and Barko 1985). Columns were placed in a growth room, where they were maintained at 25 ± 1 °C and illuminated to approximately $400 \mu\text{mol quanta m}^{-2} \text{sec}^{-1}$ of photosynthetically active radiation for 14 hr/day. After 6 weeks of growth, aboveground parts of plants were harvested, dried to a constant weight at 80 °C, and weighed to determine the final biomass.

Sediments from the bioassays were analyzed to determine bulk density, organic content, and particle size distribution. Sediment moisture content and bulk density were determined by weighing a known volume of wet sediment, drying the sample to a constant weight at 105 °C, (Håkanson 1977) and reweighing it. Organic content was determined by loss on ignition at 550 °C (American Public Health Association 1985). Particle size distribution was determined by first sieving the sediments through 6.3- and 2.0-mm mesh sieves and then determining the size distribution of finer particles by the hydrometer method of Patrick (1958).

3 Results

Results of the bioassays are shown in Figure 3. Sediments differed by approximately a factor of 5 in their ability to grow *M. spicatum*. Plants on 86 percent of the sediments produced biomass that was within the expected range (i.e., 95-percent confidence interval) for growth on the reference sediment, while the remaining sediments supported significantly less growth than the reference sediment. About one-half of the sediments supporting significantly less growth than the reference sediment were from continuously vegetated sites; the remainder were from sites where vegetation had declined or had never been present.

None of the sediment parameters measured provided a particularly good predictor of biomass production. Biomass production was significantly correlated with the clay content of sediments, but this correlation only accounted for 22 percent of the variance ($r^2 = 0.22$).

Analysis of variance (ANOVA) detected no significant differences in biomass production on the sediments from areas having different *Myriophyllum spicatum* histories (Figure 4). Similar analyses for the other parameters measured in this study revealed that only light availability (expressed as Secchi disk depth divided by water depth) varied significantly between areas of differing *M. spicatum* histories. Light availability was highest in continuously vegetated sites and was significantly lower in sites where vegetation had declined or was never present (Figure 5). Sites where vegetation had declined and recovered had an average light availability that was intermediate between that of continuously vegetated sites and decline sites.

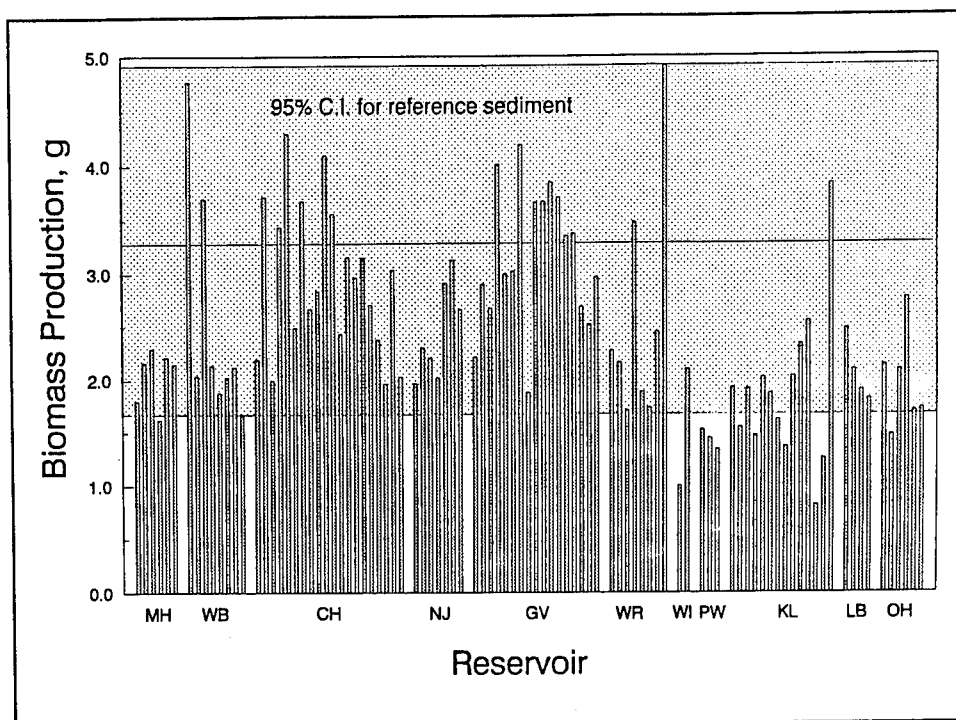


Figure 3. Growth of *Myriophyllum spicatum* plants on sediments from Tennessee and Cumberland river reservoirs (Each bar represents dry weight biomass produced on an individual sediment sample from indicated reservoir (MH = Melton Hill, WB = Watts Bar, CH = Chickamauga, NJ = Nickajack, GV = Guntersville, WR = Wheeler, WI = Wilson, PW = Pickwick, KL = Kentucky Lake, LB = Lake Barkley, OH = Old Hickory). Shaded region indicates 95-percent confidence interval for growth of plants on reference sediment from Browns Lake)

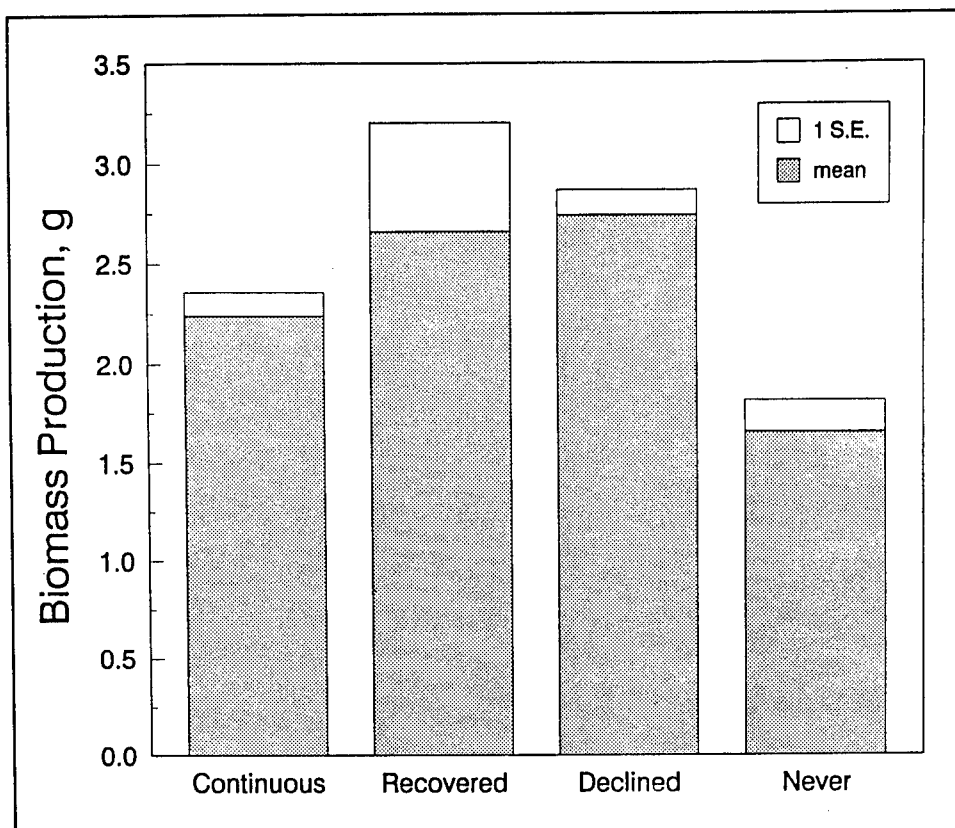


Figure 4. Growth of *Myriophyllum spicatum* plants on sediments from sites with differing *M. spicatum* cover histories (Cover history categories refer to sites where *M. spicatum* coverage from 1988 to 1993 was continuous (Continuous), had declined and recovered (Recovered), declined and not recovered (Declined), or where *M. spicatum* had never occurred (Never))

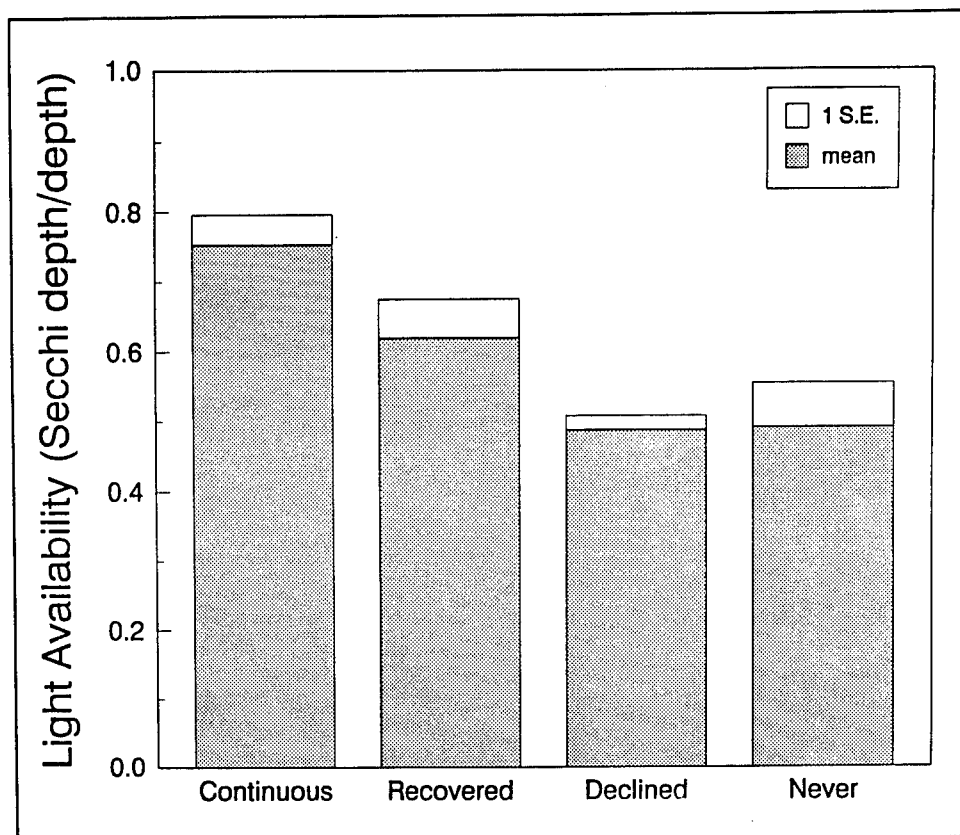


Figure 5. Light index for sites with differing *M. spicatum* cover histories (See Figure 4 for key to cover histories)

4 Discussion

The results of plant growth bioassays indicate that sediment-related mechanisms, such as nutrient depletion or organic accumulation, probably did not contribute to the 1988-91 decline in submersed vegetation in TVA reservoirs. The absence of systematic sediment differences between decline and non-decline sites, coupled with the observed differences in light regime between these areas, corroborate assertions that the decline probably resulted from effects of climatic factors that reduced light availability in 1989 through 1991 (Scott 1993). By using Secchi depth divided by water depth as measure of light regime, the effects of differences in water clarity and depth were integrated. The integrated measure worked well to separate sites because sites where *M. spicatum* populations had recovered typically had higher water clarity but were deeper than continuously vegetated sites.

Other causes are possible, but most are not likely. The role of insects and pathogens was evaluated in separate studies coordinated with this one. None of the insect herbivores reported to impact *M. spicatum* were found in plant samples collected simultaneously with the samples used in this study.¹ The potential role of a pathogen or pathogen(s) in the decline is unclear. *Mycotropha terrestris*, a fungus that has been shown to impact *M. spicatum* in laboratory and greenhouse tests, was found in moderate numbers in plant samples from all reservoirs sampled.²

One reason there has been so little success in attributing specific causal mechanisms to particular macrophyte declines is that many different phenomena, presumably having different causes, are lumped together as declines. Submersed macrophyte populations typically exhibit substantial fluctuations from year to year, and it is very difficult to separate short-term fluctuations from long-lasting reductions in coverage and biomass. These authors suggest categorizing declines based on their duration, scope, and geographical extent (Table 1) in order that different mechanisms can be identified for various classes of declines. The decline reported here was relatively short-lived

¹ Personal Communication, 1995, Michael Grodowitz, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

² Personal Communication, 1995, Judy Shearer, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Table 1 Characteristics Used to Classify Macrophyte Declines		
Duration	Scope	Extent
Intra-annual	One species	One lake
Interannual	Several species	Several
Several years	Entire type	Lakes
Permanent	Several types	Regional

(i.e., about 3 years in duration) and coincided with declines in submersed vegetation over broad areas of the eastern United States. These characteristics suggest a climatic cause.

These authors suggest that declines of exotic submersed macrophytes are more likely to involve sediment-related mechanisms in natural lakes than in reservoirs. Reservoirs represent a dynamic sedimentation environment, with substantial potential for erosion and deposition. None of the samples evaluated in this study were the very fine, flocculent sediments that often accumulate under *M. spicatum* populations in lakes. In reservoirs, such sediments would likely be removed by erosion or altered by inorganic sedimentation. In lakes, such sediments often accumulate, leading to a poor substrate for plant growth (Barko and Smart 1986).

Declines caused by alterations of the sediment beneath exotic macrophyte populations would be expected to be local and relatively long-lasting. The decline of *M. spicatum* in Lake Wingra from 1977 to 1978 (Carpenter 1980) had characteristics consistent with sediment-related causes, i.e., it was confined to several lakes that had supported *M. spicatum* populations for similar lengths of time, and *M. spicatum* has not ever regained its former dominance in them. Future investigations of the contribution of sediment-related mechanisms to macrophyte declines should target such local, long-lasting declines.

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